How much protection do FCC Part 15 Conducted Noise Limits Provide?

Will your radio *work* at your EOC?

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February 2024 / TECHCON 10

Goal

- Provide guidance to facility designers so that incidental or unintentional radiators will not disrupt or hamper backup High Frequency (HF) radio communications by radiating noise.
- Answer the question of whether advertised compliance with FCC Part 15 conducted noise limits is sufficient protection.

HF Backup Communications

- Dangerous world.
- Public switched telecommunications have multiple vulnerabilities not only to weather, but also to malicious intent of hackers or state actors
- HF communications are infrastructure-independent.
- Government, military and private entities therefore often use HF as a backup.

- Examples include Florida Division of Emergency Management using federally provided SHARES frequencies / log-periodic and loop antenna for backup communications to Florida Counties
- Military using NVIS and other communications for battlefield communications
- Traditional backup Embassy long-range communications.
- Recent interest by stockbrokers for decreased latency communications.

- Damage to HF backup communications can severely hamper coordination and control in the event that normal communications are overloaded or damaged.
- Examples include Katrina, Iowa derecchos and many more instances where weather degraded normal comms, misaligned microwave antennas, downed towers, or fire engulfed facilities.

Path Budget

- HF communications may be operating at the tail end of the allowable path budget.
- Adding 10dB of noise beyond background can be extremely disruptive to HF communications.

Unavoidable Noise

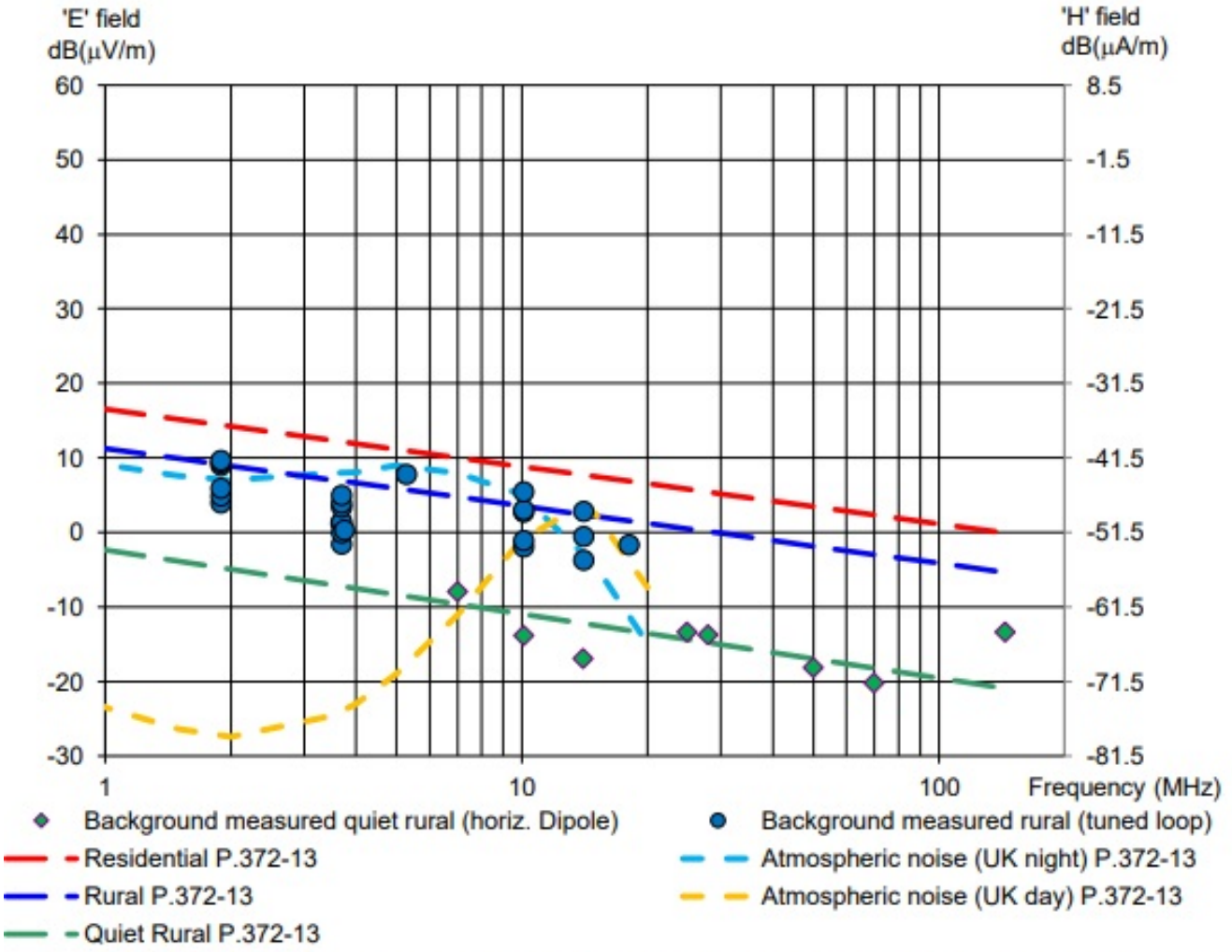


Figure 1 ITU/R P.372-13 expected receiver noise levels together with levels measured by RSGB EMCC 2014 to 2017.

REF: https://rsgb.org/main/files/2017/12/221216-Noise-leaflet-issue-2.pdf, page 3

FCC Limits

- Above 30MHz Part 15 (and European CISPR regulations) require measurement of RADIATED noise.
- Below 30 MHz, only conducted noise is regulated.
- Why?

Inefficient Radiators

- Conventional engineering wisdom: antenna < 1/6 wavelength is inefficient
- Primary radiator of many devices is their power cord, which is short.
- Building wiring is highly variable and cannot be specified.
- Therefore, the only known radiator (power cord) is inefficient.
- More effective to limit the CONDUCTION of noise into that wiring, which will limit the power available to the (unknown) eventual building wiring.

FCC Conducted Noise Limits

Device Class	Frequency of emission	Average Conducted limit, dB microvolt
A	0.5-5 MHz	60
	5-30 MHz	60
B and all others	0.5-5 MHz	46
	5-30 MHz	50

Table 1: FCC Part 15 conducted noise limits for incidental radiators in the frequency ranges of interest for NVIS communications.

Class B = residential; Class A = commercial, etc.

Alachua County

- Existing EOC has tremendous RF noise detected inside, on the roof, on the ground wiring, and everywhere throughout, presumably from computers and switching backup supplies.
- This necessitated very long coaxial cable runs to place antennas at good distances from the building.
- County is renovating a structure for a new EOC and proposes to put in uninterruptible power supplies potentially re-creating the problem.

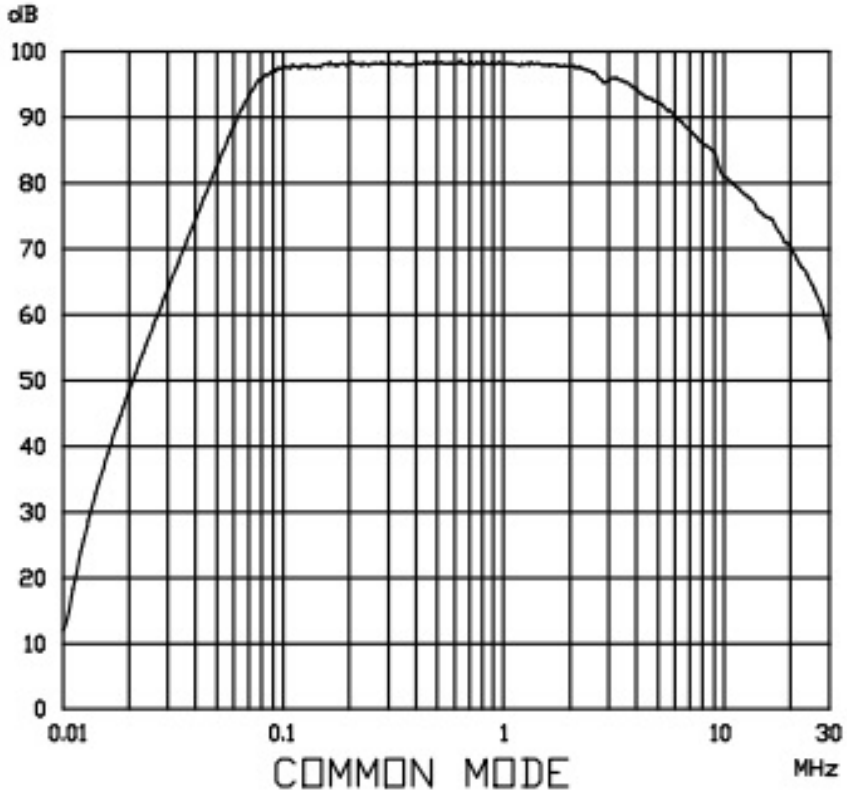
- Need to be able to advise designers now to specify equipment and installations that will NOT recreate the problem.

Device Under Test

- 3400 Watt Dual Fuel (Propane/Gasoline) inverter-based generator advertising Class B compliance.

Known Noise Maker

- Our team has considerable experience with this inverter generator (and others) and knows that extensive filtering (>50dB) is required to allow it to operate in the neighborhood of HF antennas. (Despite Class B rating)

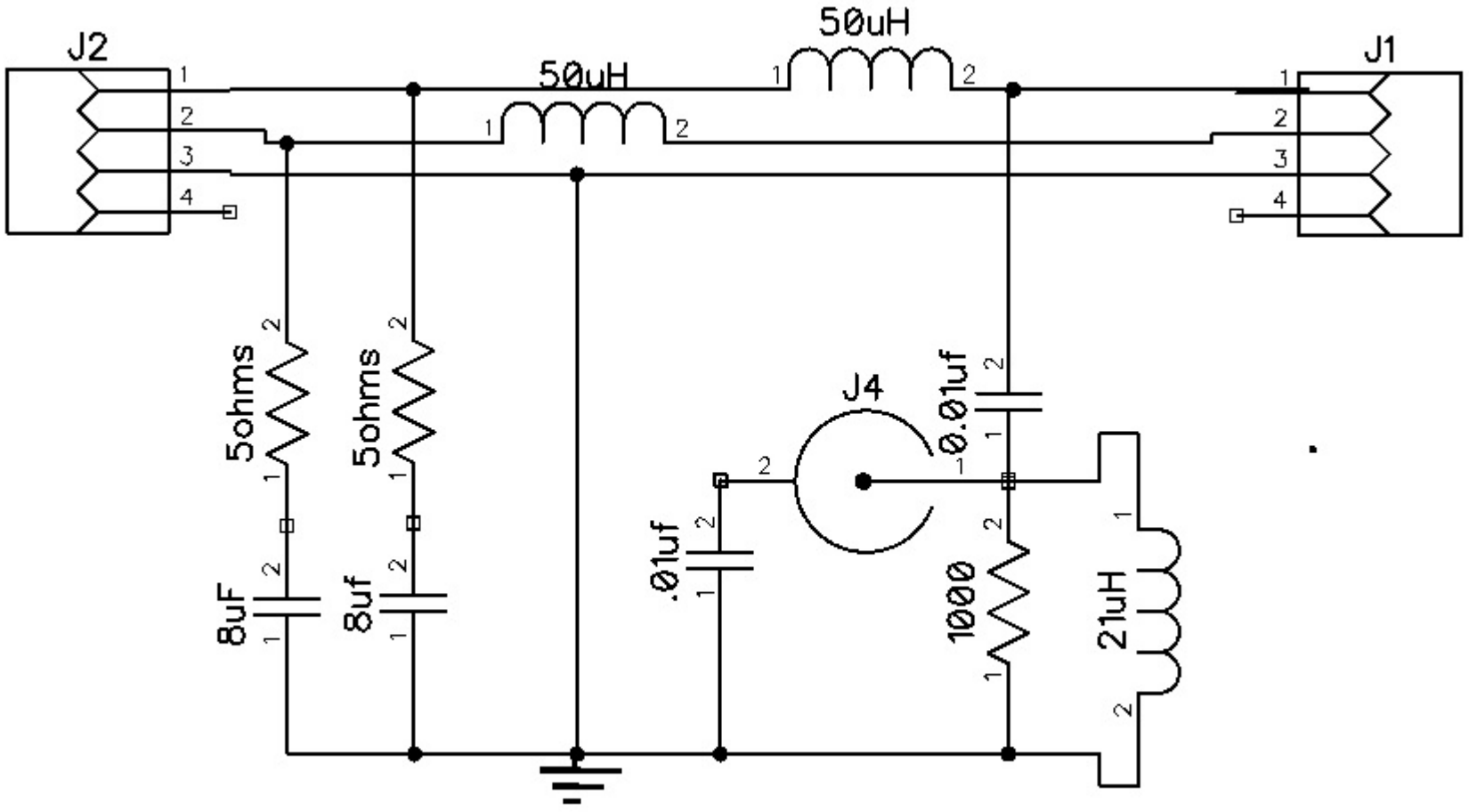


REFERENCE: https://cdn.automationdirect.com/static/manuals/emifilters/MIF23.pdf
"Filter Insertion Loss Characteristics, CISPR 17 – 50 Ohm method"

METHOD

- Conducted Noise Measurement

V-type LISN constructed



Purpose of FCC-required LISN

- In case of device requiring AC power, prevents noise from AC lines reaching device and contaminating test.
- Provides 50 ohm load for frequencies of interest to device
- Provides separating impedance (50 uH) thought to simulate 30meters of house wiring.
- These devices are extremely $$$$

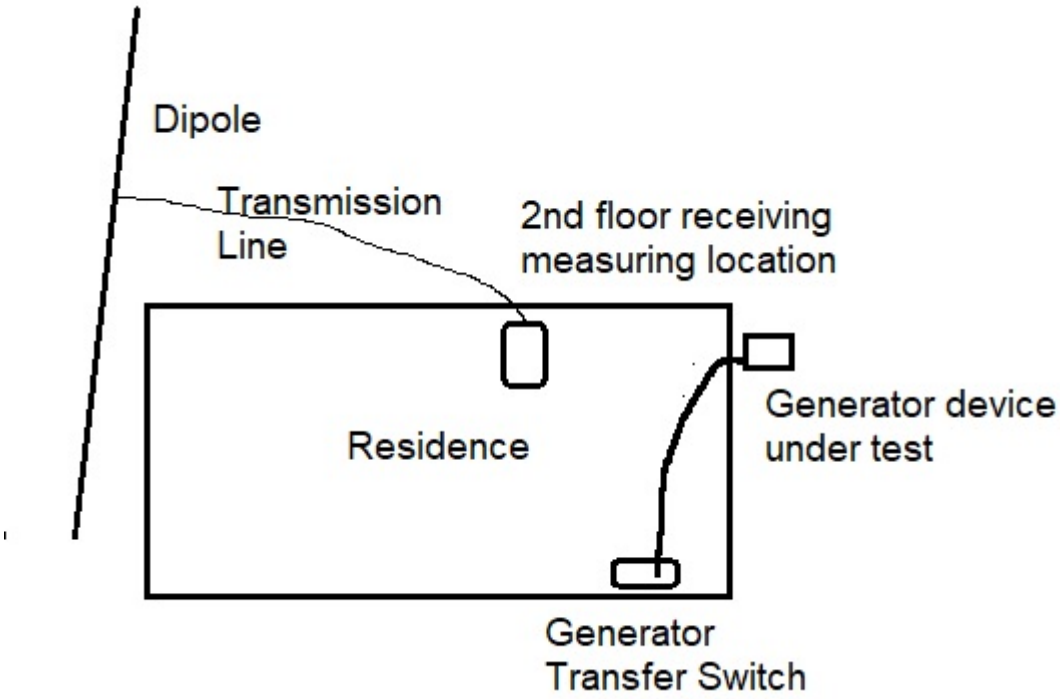
- Monitor Tap: 0.01uF cap instead of 0.1 (easily handles lowest frequency of interest)
- High Pass Filter (500kHz) added to reduce overloading of spectrum analyser by lower order harmonics (distortion) of the inverter output as not concerned by those.
- Sufficient external 50 ohm pad attenuators used to allow analyzer to operate.
- Measurements at 3.5, 7, 10.1 MHz. 10 kHz BW (nearest available to 9kHz standard)

- Adequacy of LISN assessed by measuring SWR from the “hot” side.

- NOISE MEASUREMENT – combined differential + common mode measured from both hot and neutral wiring from generator versus ground.
- Generator GROUNDED by approx 5 foot #14 wire directly to solid ground rod.
- Note this is DIFFERENT from FCC prescribed measurement (DUT on 80cm high table, grounded only through cable, ground plane underneath)

- Radiated Noise Measurement

- Not-to-Scale approximate physical setup.
- When appropriate, generator powers 2nd floor and portions of 1st floor



Antenna

- Non-resonant antenna approx 100 feet long
- 300 ohm window line to T tuner
- Assumption made that antenna is “full sized” for each band.

- At each frequency, manual T-type antenna tuner set for SWR<= 1.5:1
- Measurement of received energy taken at 3.5, 7, 10.1 MHz @ 10kHz Bandwidth
- Noise floor of spectrum analyser measured
- Baseline received without generator.
- Measurement with generator powering house.

Relevant RF Equations

Conducted measurements

$dBuV = 107dB + dBm_{spectrum\ analyzer}$ (Eq 1)

Radiated measurements

$E\ dBuV/m = 107dB + dBm_{spectrum\ analyzer} + AF\ (dB)$ (Eq 2)

where Antenna Factor (AF) conversion is found from

$Antenna\ Factor = 9.72 / (\lambda * G^{(1/2)})$ (Eg 3)[22]

where

λ = wavelength of the measurement frequency, and

G is the gain of the antenna. As our antenna subtends a significant azimuthal arc from the center of the residence, assuming a gain of unity does not introduce too great an error, since at best the gain of a dipole over isotropic is 2.1 dB.

AF for full size dipole

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RESULTS

- Assessment of adequate of home constructed LISN

Frequency MHz	VSWR measured
2	1.1
3	1.0
4	1.0
5	1.1
6	1.2
7	1.2
8	1.3
9	1.3
10	1.3

Conducted Noise Measurements

The results of conducted noise voltage noise floor, and measurements on both "hot" and "neutral" generator output, as dBm measurements from the spectrum analyzer are given in Table 4.

Frequency MHz	Noise Floor dBm	Measured noise power "hot" phase conductor dBm	Measured noise power "cold" neutral conductor dBm
3.5	-60 dBm	-18 dBm	-18 dBm
7	-59.7 dBm	-29 dBm	-28.9 dBm
10.1	-60 dBm	-41 dBm	-40 dBm

Table 4. Conducted Noise Measurements by Spectrum Analyzer

SIGLENT
2024-02-10 14:47:08
Header (Default Page Style)
Ref 0.00 dBm
Att 10.00 dB
Marker3 10.094667 MHz -40.00 dBm
LOG
10 dB
Offset
32 dB
Free
LgPwr
Cont
FFT
Marker
10.094667 MHz
-40.00 dBm
Center 11.500000 MHz
RBW 10.000 kHz
VBW 10.000 kHz
Span 17.000000 MHz
SWT 255.843 ms
A View
P-PK
B View
P-PK
C AVG 100
P-PK
Marker Table
Marker Trace Readout X Axis Ampt
Marker1 C Frequency 3.498667 MHz -18.29 dBm
Marker2 C Frequency 7.012000 MHz -28.78 dBm
Marker3 C Frequency 10.094667 MHz -40.00 dBm
Marker4 C Frequency 14.016000 MHz -52.45 dBm
Select Marker
1 2 3 4
Select Trace
C
Normal
Delta
Delta Pair
Delta
Relative To
3
Off
Marker Table
On Off
Local

Conducted Noise in FCC Units

Frequency MHz	Worst conducted measured noise power of either output terminal	Computed conducted noise voltage	Compared to Class A limit	Compared to Class B limit
3.5	-18 dBm	89.0 dBuV	Over the 60dBuV limit by 29dB	Over the 46 dBuV limit by 43 dB
7	-28.9 dBm	78.1 dBuV	Over the 60dBuV limit by 18.1 dB	Over the 50 dBuV limit by 28.1 dB
10.1	-40 dBm	67.0 dBuV	Over the 60dBuv limit by 7 dB	Over the 50 dBuV limit by 17 dB

Received Noise

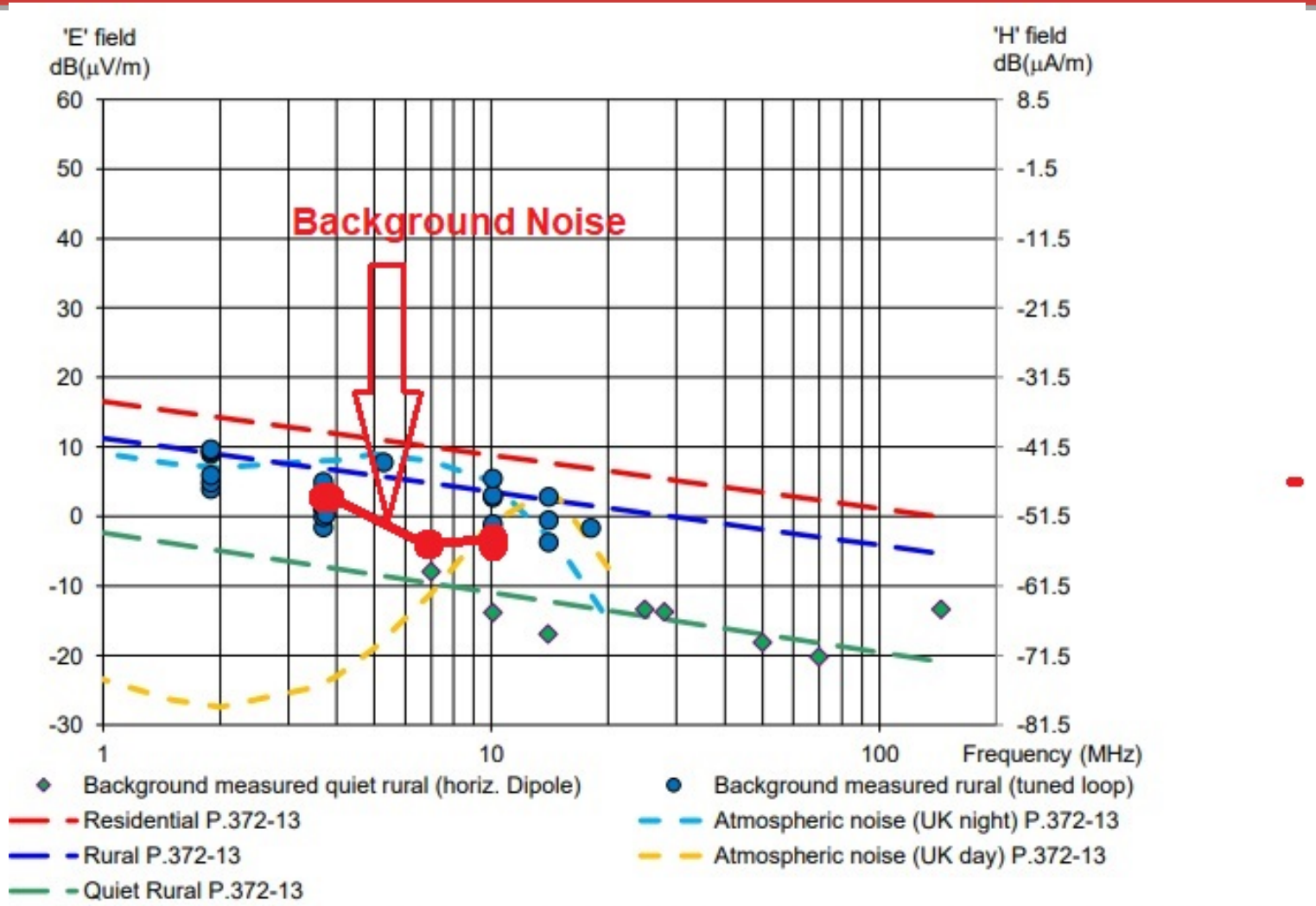
Frequency MHz	Approximate time of measurement	Analyzer noise floor, 10 kHz bandwidth	(Control) Noise (powered by utility, dBm) 10 KHz BW	(Control) Background Noise E-field powered by utility, dBuV/m 10 kHz	Noise powered by inverter generator dBm 10 kHz (20 dB internal att. to avoid ADC overload)	Background Noise E field powered by inverter generator, dBuV/m 10 kHz	Degradation by inverter generator
3.5	2 pm local	-119.4 dBm	- 86dBm	2.1 dBuV	-47.5 dBm	+40.6 dBuV/m	Degraded by 38 dB
7	2 pm local	-119.3 dBm	-97dBm	-2.9 dBuV	-82 dBm	+12.1 dBuV/m	Degraded by 15 dB
10.1	2 pm local	-119.1 dBm	-99dBm	-1.7 dBuV	-81 dBm	+16.3 dBuV/m	Degraded by 18 dB

Table 6: Degradation measurements resulting from noise radiation by household wiring of device

DISCUSSION

- Grounding and generator placement enhanced radiation – but are prudent and normal expected safety procedures
- Generator is 6 years old.
- LISN data suggest adequate performance of LISN
- Background RF measurements fall nicely of RSGB data between “Rural” and “Quiet Rural” suggesting appropriateness of AF

Background noise measured



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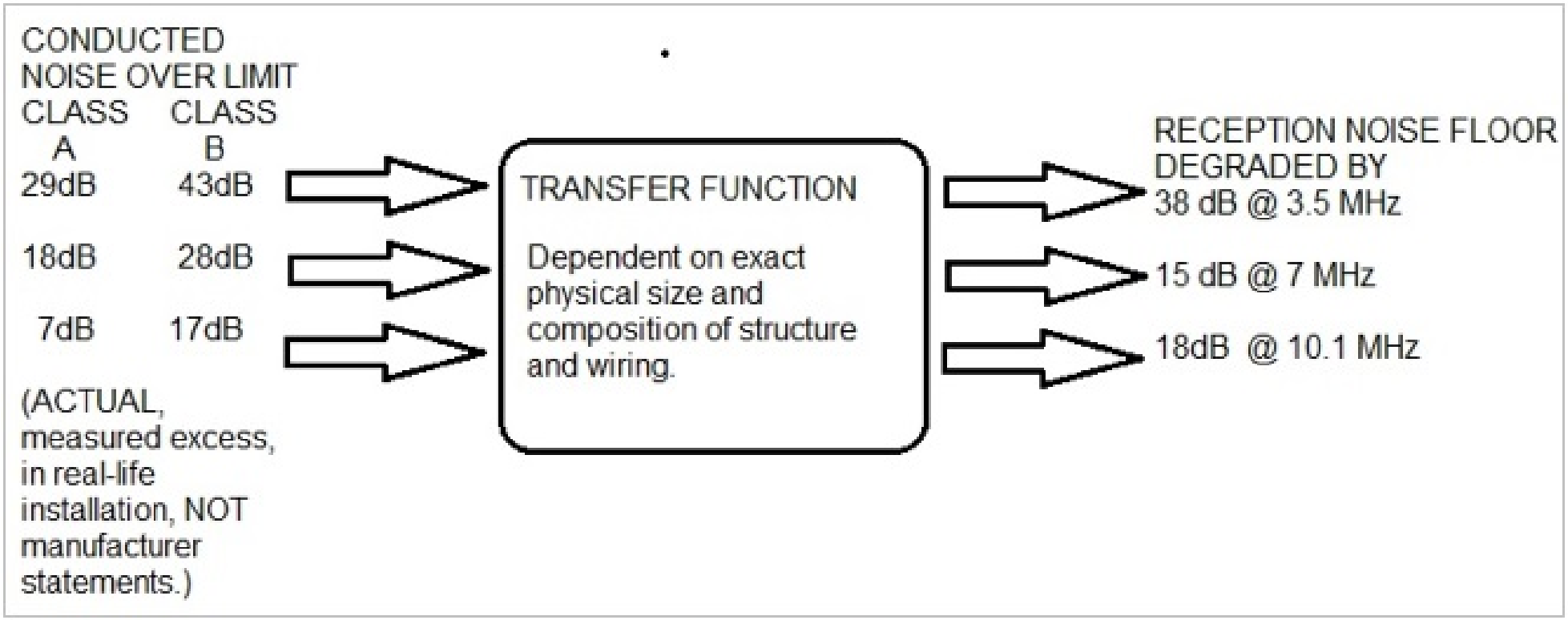
Passive Environment

- Key understanding that the environment is LINEAR. ie. Doubling noise radiated will double noise received.
- Therefore all results can be linearly scaled down to “control background” to find the necessary limit on ACTUAL conducted noise to avoid hampering RF reception.

Computation of Required Performance

Frequency	Worst transgression of Class A Standards by device under test	Worst transgression of Class B standards by device under test	Degradation of received sensitivity measured	Implied Conducted Noise Requirement to Avoid Degradation
3.5 MHz	Noise over regulatory limit by 29dB	Noise over regulatory limit by 43 dB	Degraded by 38 dB above normal background noise	Must in actual usage be measurably *under* Class A standards by 9 dB or *at or below* (meet) Class B standards.
7.0 MHz	Noise over regulatory limit by 18.1 dB	Noise over regulatory limit by 28.1 dB	Degraded by 15 dB above normal background noise	Must in actual usage be measurably *at or below* either Class A or Class B standards.
10.1 MHz	Conducted noise over regulatory limit by 7 dB	Conducted noise over regulatory limit by 17 dB	Degraded by 18 dB above normal background noise	Must in actual usage be measurably *under* Class A standards by 11 dB or *under* Class B standards by 1 dB

Illustrative Results



This one anecdotal situation:

- Stated compliance with FCC limits – even Class B limits – is NOT ENOUGH
- ACTUAL performance in realistic situation is far more important.
- 80 meters: Req. 9DB below Class A or meet Class B
- 40 meters: Req actually meeting either A or B
- 30 meters: Req actually under Class A by 11 dB or under Class B by 1 dB

- Only one situation studied.
- Actual performance far more important than contrived laboratory claims
- Inadequate performance can be salvaged by
  - Pre filtering with industrial filters safely mounted
  - Prefiltering with some consumer filters available

https://www.digikey.com/en/products/detail/qualtek/849-20%2F004/1680215

https://www.apc.com/us/en/product/C2/apc-av-c-type-2-outlet-wall-mount-power-filter-120v

https://tripplite.eaton.com/isobar-2-outlet-surge-protector-direct-plug-in-1410-joules-3-leds-black-housing-5-in-height~ULTRABLOK

Consequences of failure to protect

- Hampered communications at all times
- Volunteers will be acutely aware
- Facility will be judged substandard
- Attrition of volunteers
- Resulting loss of federal “match”
- Lack of capability when needed

Questions / Comments?

Thank You!